

## **Tensile Properties of Long Jute Fiber Reinforced Polypropylene Composites**

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**Abstract**—Now-a-days the need for Composite materials has widely increased. Keeping in view the environmental factors caused by the synthetic fibers like carbon, glass fibers etc has led to the requirement of natural fibers like jute, hemp etc which are environmentally friendly, low cost and easily available. Synthetic fibers like carbon or glass are widely used in industry but their cost is high so a need for naturally available and low cost fibers has arrived. Jute, hemp etc are the natural fibers which can be used as reinforcement material. The main objective of our project is to test the tensile properties of the long and continuous natural fiber reinforced polypropylene composites. The natural fiber used in our project is jute fiber and the reinforcement used is continuous or long fiber reinforcement. The fibers for better adhesion property are first chemically treated with NaOH at different concentrations (5%, 10% and 15%). These treated fibers with different weight ratios (2.5%, 5%, 7.5% and 10%) are used with polypropylene matrix. The samples are prepared by injection molding and hand layup technique as per ASTM standards and tested on Universal testing machine and results are analyzed. The results have shown that, for treated jute fiber reinforced polypropylene samples the tensile strength and tensile modulus are more than the plain polypropylene samples. There is 28.4% increase in the tensile properties of 15%NaOH treated fiber reinforced polypropylene samples with 10% weight ratio of jute when compared to Plain Polypropylene samples. Chemical treatment increased the surface roughness and improved the bonding thereby resulting in increased tensile properties.

### **I. INTRODUCTION**

Composites are structures that are made up of diverse elements, with the principle being that the sum of the whole is greater than the sum of its component parts (i.e.  $1+1=3$ ). An understanding of composites seems to be inherent in animal behavior, evident in the nest building of birds, bats and insects, for example. Primitive man used the basic materials that were available to him such as animal dung, clay, straw and sticks to form composite structures that were literally the first building blocks of civilization. Even the biblical Noah's Ark was allegedly made of coal-tar pitch and straw, which could perhaps be the first reported construction of a reinforced composites boat! Moving forward several thousand years, and the second wave of the industrial revolution that swept through western Europe from the 1830s onwards, saw new found industries developing their own composite technologies such as laminated wood, alloyed metals and steel reinforced concrete. The earliest polymer castings were developed by Lepage in France using albumen, blood and wood flour to produce decorative plaques. The first semi - synthetic plastics were produced when cellulose fibers were modified with nitric acid to form cellulose nitrate - or celluloid as it was to become known. Today, the composites marketplace is widespread. As reported recently by the SPI. Composites Institute, the largest market is still in transportation (31%), but construction (19.7%), marine (12.4%), electrical/electronic equipment (9.9%), consumer (5.8%), and appliance/business, equipment are also large markets. The aircraft/aerospace market represents only 0.8% which is surprising in light of its importance in the origins of composites. Of course, the aerospace products are fewer in number but are much higher in value.

#### **What is a composite?**

A composite is a product made with a minimum of two materials – one being a solid material and the other a binding material (or matrix) which holds together both materials. There are many composite products with more than two raw materials. Those materials are not miscible together and are of a different nature. Composite materials are engineered or naturally occurring materials made from two or more constituent materials with significantly different physical and chemical properties which remain separate and distinct at the macroscopic and microscopic scale within the finished structure. Composite materials are multiphase materials obtained through the artificial combination of different materials in order to attain properties that the individual components by themselves cannot attain. They are not multiphase materials in which the different phases are formed naturally by reactions, phase transformations, or other phenomena. An example is carbon fiber reinforced polymer. A structural composite is a material system consisting of two or more phases on a macroscopic scale, whose mechanical performance and properties are designed to be superior to those of the constituent materials acting independently. One of the phases is usually discontinuous, stiffer and stronger and is called reinforcement, whereas the less stiffer and weaker phase is continuous and is called matrix. Sometimes because of chemical reactions or other processing effects, an additional phase called interphase, exists between the reinforcement and matrix. In our project the matrix is polypropylene and the reinforcement is jute fibers.

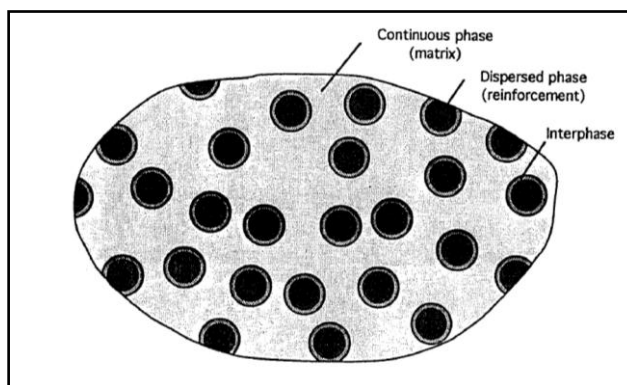


Fig 1.1: Phases of a composite material.

## II. EXPERIMENTAL WORK

### 2.1 Materials

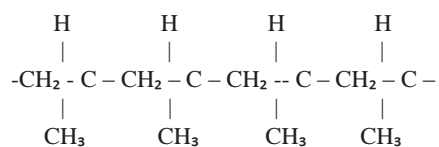
#### Polypropylene

It is produced by the polymerization of propene using the Zeigler-Natta catalysts (AL (iso - C<sub>4</sub>H<sub>9</sub>)<sub>3</sub> and TiCl<sub>3</sub>). Propylene can be prepared as isotactic, syndiotactic or atactic forms.

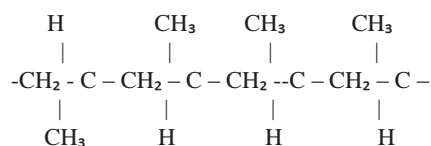


Fig2.1: Polypropylene granules

**Isotactic:** - it is the configuration or arrangement in which the functional groups are arranged in the same side

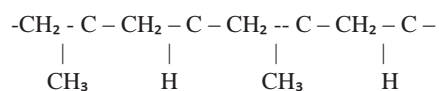


**Atactic:** - it is the configuration or arrangement in which the functional groups are arranged randomly.



**Syndiotactic:** - is the configuration or arrangement in which the functional groups are arranged in an alternating manner.





The isotactic pp melts at 170°C and highly crystalline. Being highly crystalline pp exhibits high stiffness, hardness and tensile strength. But at the same time pp is one of the lightest polymer. Its high strength to weight ratio makes it an industrial or engineering polymer. It is also highly resistant to many inorganic acids, alkalies and chemicals. But it has a lesser stability towards heat and light when compared with HDP. But at the same time pp has excellent mechanical properties.

#### Uses

PP plastic is mainly produced by injection moulding. Luggage box, battery cases, tool boxes are made of pp polymer. Filament of fiber of pp is used in making carpets, ropes etc. it has an excellent insulator purpose. pp components are used in T.V. Radio, Refrigerators parts, storage tanks for chemicals, seat covers. The polypropylene has been purchased from Marama Chemical Ltd., near Autonagar.

#### JUTE FIBERS :

Jute fibers are naturally available fibers. They are extracted from the bast plants. Water retting process is implemented to separate fibers from the core of the bast plants. These semi-retted jute fibers have been purchased from Kankipadu Farmers Market., near Kankipadu, Vijayawada.

#### 2.2. Fiber Extraction

Retting is the process of extracting fiber from the long lasting life stem or bast of the bast fiber plants. The available retting processes are: mechanical retting (hammering), chemical retting (boiling & applying chemicals), steam/vapor/dew retting, and water or microbial retting. Among them, the water or microbial retting is a century old but the most popular process in extracting fine bast fibers. However, selection of these retting processes depends on the availability of water and the cost of retting process. To extract fine fibers from jute plant, a small stalk is harvested for pre-retting. Usually, this small stalk is brought before 2 weeks of harvesting time. If the fiber can easily be removed from the Jute hurd or core, then the crop is ready for harvesting. After harvesting, the jute stalks are tied into bundles and submerged in soft running water. The stalk stays submerged in water for 20 days. However, the retting process may require less time if the quality of the jute is better.

When the jute stalk is well retted, the stalk is grabbed in bundles and hit with a long wooden hammer to make the fiber loose from the jute hurd or core. After loosening the fiber, the fiber is washed with water and squeezed for dehydration. The extracted fibers are further washed with fresh water and allowed to dry on bamboo poles. Finally, they are tied into small bundles to be sold into the primary market.

These bundles of fiber are bought and then soaked in water and dried in sunlight. After drying it is cleaned from dust by vigorous rubbing and combing and then cut as per required length. Bunches of fibers of 10 gms each are made and sent for chemical treatment.



*Fig 2.2: Soaking jute in water*



*Fig 2.3: Rubbing the jute to separate dust and fiber*



*Fig 2.4: Combing technique to remove knots*



*Fig 2.5: Extracting individual fibers from*



*Fig 2.6: Bunches of fibers before weighing the clean bunch*

### **3.3 Chemical Treatment**

The Fibers are to be treated with NaOH to increase their surface roughness and to improve adhesion property. A few bunches are treated with 5% NaOH and a few with 10% and 15% NaOH. These bunches are soaked in NaOH for 3 hrs and then washed with distilled water and then for 20mins are soaked in acetic acid solution. Again the samples are washed with distilled water and are soaked in 6%  $H_2O_2$  and continuously stirred for 2 hrs. These bunches are then washed again with distilled water and dried in sunlight.



*Fig 2.7: Fiber soaked in 5% NaOH*



*Fig 2.8: Fiber soaked in Acetic acid*

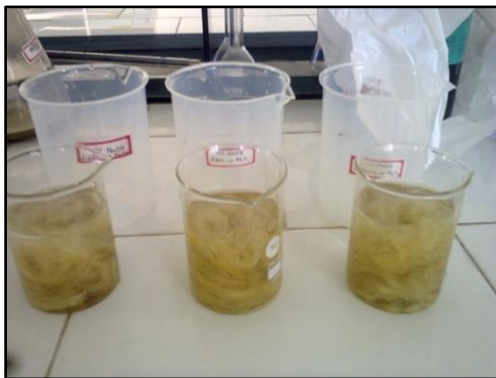




*Fig 2.9: Fibers soaked in  $H_2O_2$*



*Fig 2.10: Fibers being stirred after soaking in  $H_2O_2$*



*Fig 2.11: Fibers being cleaned with distilled water*



*Fig 2.12: Treated fibers being dried in sunlight*

### 2.3. Sample Preparation

Molds are prepared from zinc sheets by tinsmithy and the size of the molds is 160x13x3 mm.

The polypropylene granules are poured into the injection moulding material and the temperature is set to 170°C. When the Polypropylene is melted it is poured into the molds. The fibers are induced when the polypropylene is in molten state. The composite (PP + Fiber) in the mold is shook to set the polypropylene properly on fibers and then a roller is rolled over it by applying hand pressure. After cooling the composite material is removed from the mold and filed to the required dimensions. 5 samples of polypropylene are prepared and then grinded to the size 150x13x3 mm, for even surface. The average weight of the sample is 7.89 gms. 5 samples each of 2.5%, 5%, 7.5% and 10% by wt of untreated fibers are prepared. The weight of 2.5% by wt of fiber is 0.2gms, for 5% is 0.3gms, for 7.5% is 0.6gms and for 10% is 0.8gms. 5 samples each of 2.5%, 5%, 7.5% and 10% by wt of 5% NaOH treated fibers, 5 samples each of 2.5%, 5%, 7.5% and 10% by wt of 10% NaOH treated fibers, 5 samples each of 2.5%, 5%, 7.5% and 10% by wt of 15% NaOH treated fiber. So totally 80 samples of fiber + Polypropylene are prepared.



*Fig 2.13: Molds for preparing samples*



*Fig 2.14: Polypropylene being poured into the mold from injection moulding machine*



*Fig 2.15: Inserting fibers into polypropylene*



*Fig 2.16: Rolling pressure applied to the composite*



*Fig 2.17: Samples after rolling*



*Fig 2.18: Removing of samples from molds*



*Fig 2.19: Plain Polypropylene samples*







Fig2.20: 2.5%, 5%, 7.5%, 10% wt% of untreated fiber samples



Fig 2.21: 2.5%, 5%, 7.5%, 10% wt% of 5% NaOH treated fiber samples





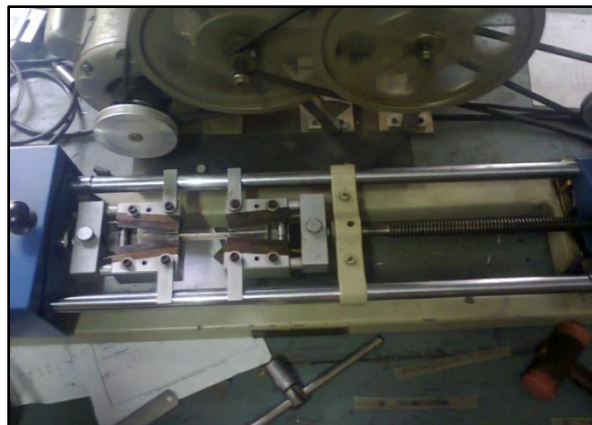
*Fig2.22: 2.5%, 5%, 7.5%, 10% wt% of 10%NaOH treated fiber samples*



*Fig 2.23: 2.5%, 5%, 7.5%, 10% wt% of 15%NaOH treated fiber samples*

#### 2.4. Testing

These Samples are tested for tensile property on a universal testing machine and the results are analysed as per ASTM standards. The samples are loaded on the machine and the maximum load is set to 200 kg and then load is applied. The elongation and their respective loads are noted. The diameters and the weights of the fibers are tested before and after chemical treatment.



*Fig2.24 Sample loaded on the machine*



### III. RESULTS AND DISCUSSIONS

#### 3.1. Calculations:

FORMULAE:

$$1) \text{ Ultimate tensile strength} = L/A \text{ MPa}$$

L = Load (N)      A = Area (mm<sup>2</sup>)

$$2) \text{ Tensile Modulus} = \text{Ultimate tensile strength} / \text{Strain (MPa)}$$

Ultimate tensile strength (MPa)

Strain = Elongation / Total length

Elongation (mm)

Total length (mm)

#### 3.2. Results:

**Table 3.1: Weights and diameters of fibers before and after chemical treatment.**

S.NO	Type of Fiber	Weights, mg	Diameter, mm
1	Untreated fibers	14.4	0.594
2	5% NaOH treated fibers	12	0.391
3	10% NaOH treated fibers	6.2	0.266
4	15% NaOH treated fibers	5	0.197



**Fig 3.1: Samples after testing**

**Table 3.2: Various parameters of the jute fiber reinforced polypropylene composite materials**

S.NO	Type of Speciman	Particle size(μm)	Load (Kg)	Load ,N	Area,mm2	Elongation (mm)	%Elongation at break	Ultimate Tensile strength (Mpa)	Strain	Tensile Modulus (Mpa)
1	Plain PP		97.425	955.7393	39	10	20	24.51	0.20	122.5
2	97.5%PP+2.5%FIBERS	UTF	95.93	941.0733	39	8.8	17.6	24.13	0.18	137.1
3		5%NaOH	98.45	965.7945	39	8.33333	16.66666	24.76	0.17	148.6
4		10%NaOH	103.55	1015.826	39	8.2	16.4	26.05	0.16	158.8
5		15%NaOH	105.23	1032.306	39	8.2	16.4	26.47	0.16	161.4
6	95%PP+5%FIBERS	UTF	95.67	938.5227	39	7.9	15.8	24.06	0.16	152.3
7		5%NaOH	100.73	988.1613	39	7.7	15.4	25.34	0.15	164.5
8		10%NaOH	104.35	1023.674	39	6.92	13.84	26.25	0.14	189.7
9		15%NaOH	109.57	1074.882	39	6.36	12.72	27.56	0.1272	216.7
10	92.5%PP+7.5%FIBERS	UTF	95.67	938.5227	39	7.5	15	24.06	0.15	160.4
11		5%NaOH	101.47	995.4207	39	6.86667	13.73334	25.52	0.137333	185.9
12		10%NaOH	117.65	1154.147	39	6.85	13.7	29.59	0.137	216.0
13		15%NaOH	121.08	1187.795	39	6.15	12.3	30.46	0.123	247.6
14	90%PP+10%FIBERS	UTF	93.26	914.8806	39	6.8	13.6	23.46	0.136	172.5
15		5%NaOH	104	1020.24	39	6.72	13.44	26.16	0.1344	194.6
16		10%NaOH	119.475	1172.05	39	5.7	11.4	30.05	0.114	263.6
17		15%NaOH	125.15	1227.722	39	5.66667	11.333334	31.48	0.113333	277.8

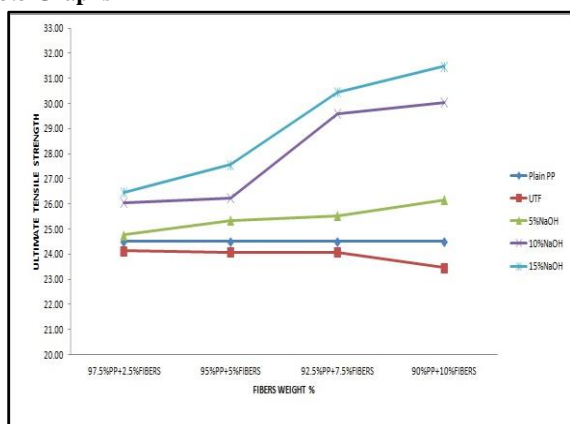
**Table 3.3: Ultimate tensile strength of the jute fiber reinforced polypropylene composite material samples.**

	Plain PP	UTF	5%NaOH	10%NaOH	15%NaOH
97.5%PP+2.5%FIBERS	24.51	24.13	24.76	26.05	26.47
95%PP+5%FIBERS	24.51	24.06	25.34	26.25	27.56
92.5%PP+7.5%FIBERS	24.51	24.06	25.52	29.59	30.46
90%PP+10%FIBERS	24.51	23.46	26.16	30.05	31.48

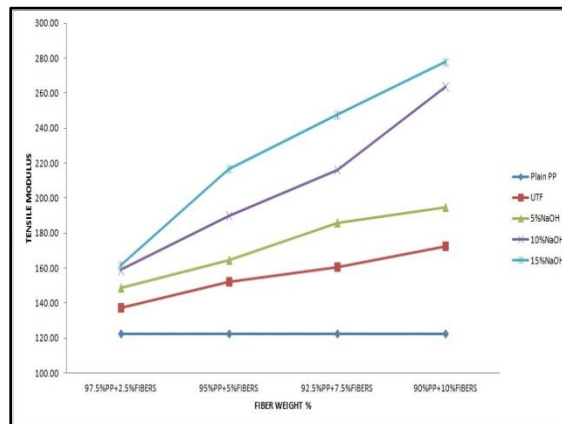
**Table 3.4: Tensile Modulus of the jute fiber reinforced polypropylene composite material samples.**

	Plain PP	UTF	5%NaOH	10%NaOH	15%NaOH
97.5%PP+2.5%FIBERS	122.53	137.10	148.58	158.82	161.40
95%PP+5%FIBERS	122.53	152.31	164.53	189.65	216.68
92.5%PP+7.5%FIBERS	122.53	160.43	185.85	216.01	247.61
90%PP+10%FIBERS	122.53	172.49	194.64	263.62	277.77

### 3.3 Graphs



**Graph 3.1: Ultimate tensile strength Vs Fiber weight Percent**



**Graph 3.2: Tensile Modulus Vs Fibers weight percentage.**

## IV. DISCUSSIONS AND ANALYSIS

Table 4.1 shows the change in weights and diameter of jute fibers before and after chemical treatment. Table 4.2 shows the various parameters of the long and continuous jute fiber reinforced polypropylene composite. The load, elongation, tensile strength, tensile modulus, mass etc are noted in this table. Table 4.3 and graph 4.1 shows the ultimate tensile strength and Table 4.4 and graph 4.2 shows the tensile modulus. From the above graphs it is shown that as the weight percentage increases, ultimate tensile strength and tensile modulus increases. It is shown that 15% NaOH treated fibers show maximum tensile strength. The orientation of fibers results in unidirectional properties.

In graph 4.1 the ultimate tensile strength of untreated fibers is less than the plain polypropylene. It is obvious that the ultimate tensile strength of the jute fiber reinforced composites becomes lower than that of the pure polypropylene matrix as the nominal fiber fraction increases. This can be explained by both the interfacial adhesion between the matrix and fiber surface and the voids in the composites. Since no coupling agent was introduced to improve the interfacial bonding in this study, mechanical interlocking without any chemical bonding may be responsible for the adhesion. The strength of this mechanical interlocking seems to be insufficient to hold the fiber and matrix together as the composite undergoes large tensile deformation, resulting in low load transfer and, subsequently, low tensile strength. The void contents may be another source of the low tensile strength, because the voids act as a stress raiser (i.e., stress concentration) that can bring about rapid failure. This tendency can be observed in the jute fiber reinforced composites.

It is clearly seen in the graphs that the tensile strength and modulus of treated fibers is greater than the plain polypropylene and untreated fibre composite. Alkali treatment generally increases the strength of natural fiber composites. A strong sodium hydroxide treatment may remove lignin, hemicellulose and other alkali soluble compounds from the surface of the fibers to increase the numbers of reactive hydroxyl groups on the fiber surface available for chemical bonding. So, strength should be higher than untreated fiber composites. The probable cause of this unlike phenomenon may be, alkali react on the cementing materials of the fiber specially hemicellulose which leads to the splitting of the fibers into finer filaments. As a result, wetting of fiber as well as bonding of fiber with matrix may improve which consequently make the fiber more brittle. Under stress, these fibers break easily. Therefore, they cannot take part in stress transfer mechanism. So, high concentration of sodium hydroxide may increase the rate of hemicellulose dissolution which will finally lead to strength deterioration. Moreover, unnecessary extra time in treatment may also cause increment of hemicellulose dissolution.

## V. CONCLUSIONS

With the results obtained from the experimental procedure, the following conclusions are made.

1. As the fibre weight percent increases the tensile strength and modulus increases
2. The ultimate tensile strength of untreated fibre is less than the plain polypropylene because of formation of voids and improper adhesion between fiber and matrix due to the lack of required surface roughness needed for bonding of fiber with matrix.
3. Due to the chemical treatment the surface roughness increases providing strong interfacial adhesion between matrix and fiber thereby increasing the ultimate tensile strength and tensile modulus.
4. The tensile strength of the fiber increases as the percentage of NaOH for treating fibers is increased. NaOH dissolves lignin, hemicelluloses and other binding materials and providing reactive hydroxyl groups on the surface of the fiber for better interfacial bonding. The generalised equation can be shown as  

$$\text{Fiber-OH} + \text{NaOH} \rightarrow \text{Fiber-O}^- \text{Na}^+ + \text{H}_2\text{O}$$

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